Power and Energy Considerations at Forward Operating Bases (FOBs)

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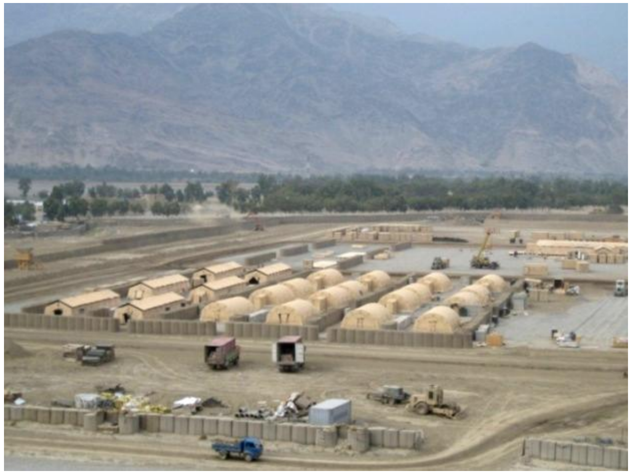
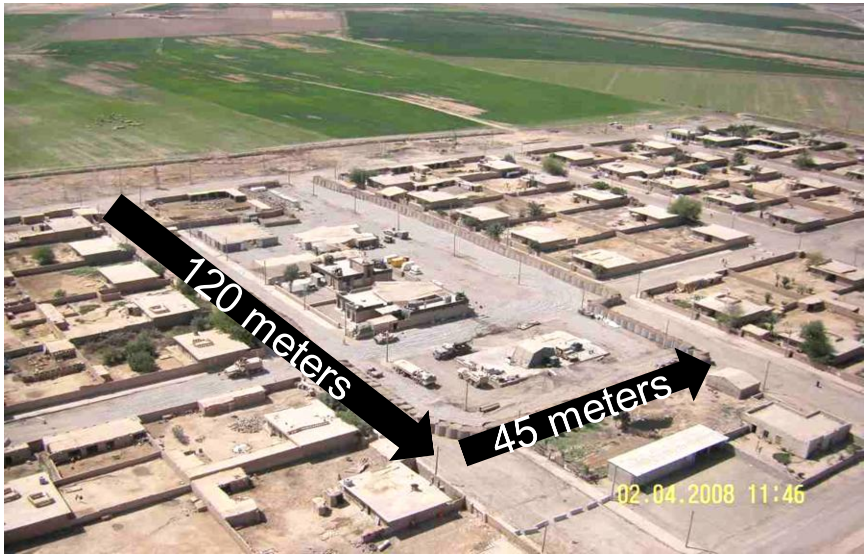
16 June 2010





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Objectives

- To determine and compare baseline planning factors for power and energy at the tactical & operational level
- To address the power and energy requirements for the operations and support of deployed base camps
    - To provide recommendations to reduce power and energy

Current Field Data:

- Unit personnel and equipment data
- Research LOGCAP and other contracts, conduct interviews: 249th Engineer Battalion (Prime Power), U.S. Marines, others
- Analysis of current building types/insulation/uses and equipment (ECU and plug loads)
- Personal Experiences: Iraq and Afghanistan, CENTCOM Staff, CONUS FOB Training Centers

References:

- USCENTCOM Sand Book & USAREUR Red Book
- US Army Field Manual 3-34: General Engineering
- 249th Engineer Battalion (Prime Power) Field Operating Manual

Power Planning Factor (kW per person)

Reference [1]	kW per person	Company (150) (kW)	Battalion (600) (kW)	Brigade (3,500) (kW)
CENTCOM Sand Book, 2008	0.7	105	420	2,450
USAREUR Red Book	Not stated by kW/person: Detailed Load Analysis Required			
FM 3-34, 2008	0.7	105	420	2,450
249th ENGR BN Interviews	3.7 kVA	555	2,220	12,950
Air Force Expeditionary Airfield	1.36	-	(550) 750	(3,300) 4,500
"Base in a Box" [2]	1.8	270	1,080	6,300

1. Does not include field hospitals
2. 10 Tents (4-ton ECU's) and 2 Latrine/Shower/Sink trailers + pumps; for 100 Soldiers

Fuel Usage (250 kW)

Gen Size (kW)	Fuel Usage (gal/hr)
250	18.0 (100%)
1000	21.6 (25%)

Fuel Usage (1000 kW Gen Set)

Load	Fuel Usage (gal/hr)	Gallon / kWhr
25%	21.6	0.0864
100%	71.1	0.0711

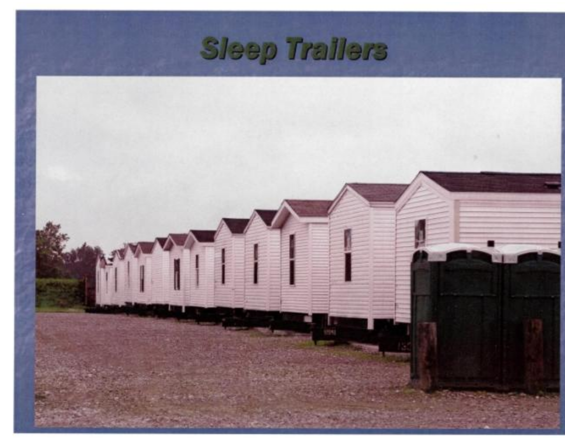
Tactical Power Generation in Army Units (MTOE) Personnel & Equipment - Required (USAFMSA Data Base)

	IBCT (Light) Infantry Bn	SBCT Infantry Bn	SBCT Spt Bn	Sustainment Bde	AVN Spt Bn	Combat Support Hospital (Up to 256 Beds)
GEN SETS (kW)	88	110	658	503	1127	1372
Soldiers Assigned	684	687	731	364	766	487
kW / Soldier	**0.13**	**0.16**	**0.9**	**1.38**	**1.47**	**2.82**

Camp Atterbury Utility Data: 2009									
FOB III	Unit	June	July	August	September	October	November	December	
Energy	kWh	50161.00	41539.00	51539.00	55973.00	64393.00	92036.00	170436.00	
Power	kW	165.60	119.40	155.40	195.00	211.20	255.00	342.00	
Princes Lake Water	Gal.	196000.00	370000.00	167000.00	384000.00	498000.00	74000.00	41000.00	
Waste/Garbage	C.Y	144.00	112.00	80.00	144.00	96.00	56.00	48.00	
Porta Jons/ X45units X5gal. Per Dayx30	Gal	6750.00	6750.00	6750.00	6750.00	6750.00	6750.00	6750.00	
Shower	Gal.	72000.00	144000.00	72000.00	144000.00	144000.00	72000.00	72000.00	
Grey Water	Gal.	72000.00	144000.00	72000.00	144000.00	144000.00	72000.00	72000.00	
Inhabitants	PAX.	620.00	1120.00	570.00	640.00	730.00	350.00	225.00	
									Average
kW/person		0.27	0.11	0.27	0.30	0.29	0.73	1.52	0.50

Camp Atterbury, IN is a CONUS pre-deployment training site.

High Voltage Distribution Boxes



Other Quantitative Issues with Base Camp Power & Energy Estimating

- Few camps are "pure" MTOE staffed, smaller FOBs an exception
  - Many are Joint, Interagency, Intergovernmental, and Multinational (JIIM)
  - Some relocate on short notice due to mission requirements
  - Some increase/decrease in size on short notice due to mission requirements
- Other support personnel can easily exceed the Soldier population
  - Contractors (LOGCAP, mentors, LN workers), AAFES + local vendors, MWR, gyms, other Gov Agencies, Coalition and HN service members
- Additional systems have high power demand requirements
  - AT/FP (lighting, barriers, etc.)
  - IT systems (landline, microwave and satellite communications)
  - Other Soldier support systems & facilities, incl. dining facilities
  - Hot Water Heaters
  - Individual surge protectors and battery backup systems
- Anticipated additional plug loads by users
  - Personal Computers and Gaming Devices
  - Coffee Pots
  - Refrigerators
  - Lights
  - Personal Heaters and Battery Chargers

2009 Field Data from USMC Afghanistan Study

- For every gallon of generator fuel used
  - it took seven gallons to transport it there
- For every gallon of bottled water transported
  - it took seven gallons of fuel to get it there
- Tactical Level: Power Demand is Small
- Generators were loaded at an average of 30%
  - HVAC is 75% of Electrical demand
  - 50% is lost by inefficient structures

Marine Energy Assessment Team, 1 October 2009

Afghanistan: Conclusions

- Pre-engineered packaged solutions (Base-in-a-Box) with generators provided the fastest facility solution, not necessarily the most efficient
- Organizations above Corps level (USFOR-A, NTM-A/CSTC-A, ISAF, RC's, major airfields) were constantly changing in size and composition, many had coalition partners. Base engineers were concerned with meeting power demand, <u>not energy efficiency</u>. Contractors (LOGCAP) were invaluable.
- Reducing energy consumption on a large scale is difficult in Afghanistan's harsh, austere, and hostile environment, and high OPTEMPO
- Because of the high OPTEMPO and lack of metering, it is assumed that determining any energy reduction (kBtu/ft2) is nearly impossible and probably not worth the effort
- Qualitatively, the most important factor in reducing energy consumption is by installing and maintaining a meaningful control scheme for the decentralized HVAC systems, providing an improved building envelope and tightness for the varying construction types and then reducing the size of the HVAC systems
- Renewables, in this environment and in the near-term, will only provide a fraction of the total energy required

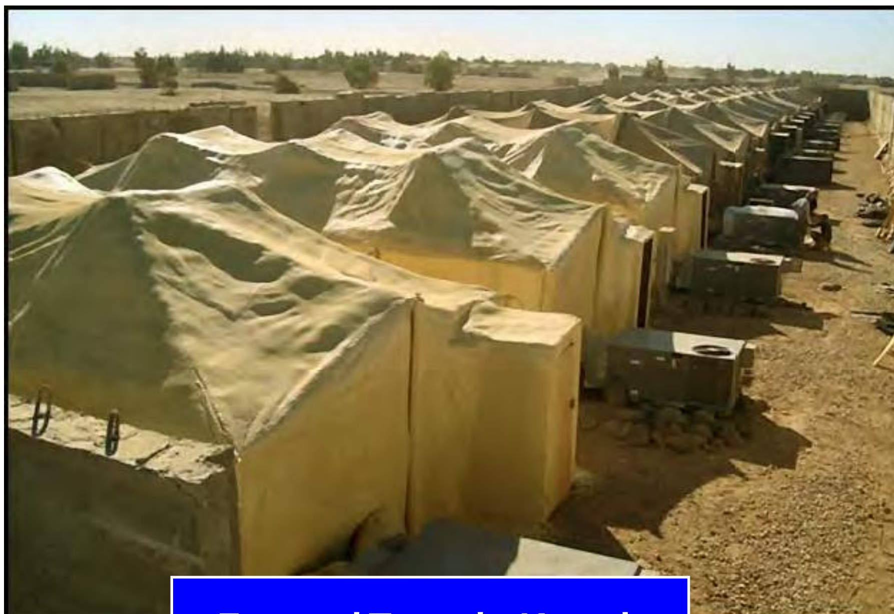
COL John Vavrin, 2009

Afghanistan: Recommendations

- Reach-back capability to optimize generators loads and distribution, master-plan electrical distribution for the larger-sized camp/bases (Kandahar, Bagram, Herat, Bastion, KIA)
- Improve the building envelope: tightness, and insulation
  - Properly size HVAC systems for each facility based on improved building envelope

Comparison of Tentage Insulation		
Tentage Insulation	ECU (tons)	kW (cooling)
Double-Lined	4	8.8
Spray-Foam / Other Insulation	2	3.3
Spray-Foam / Other Insulation	1	1.3


Base-in-a-Box, Double-Lined Tent, Camp Spann, Mazar-e-Sharif (4-ton ECU)


Foamed Tents in Kuwait


A U.S. soldier and Iraqi worker apply Terra Strong spray foam on the roof of a medical tent in Basra, Iraq.

Tent Foaming (Pros & Cons)

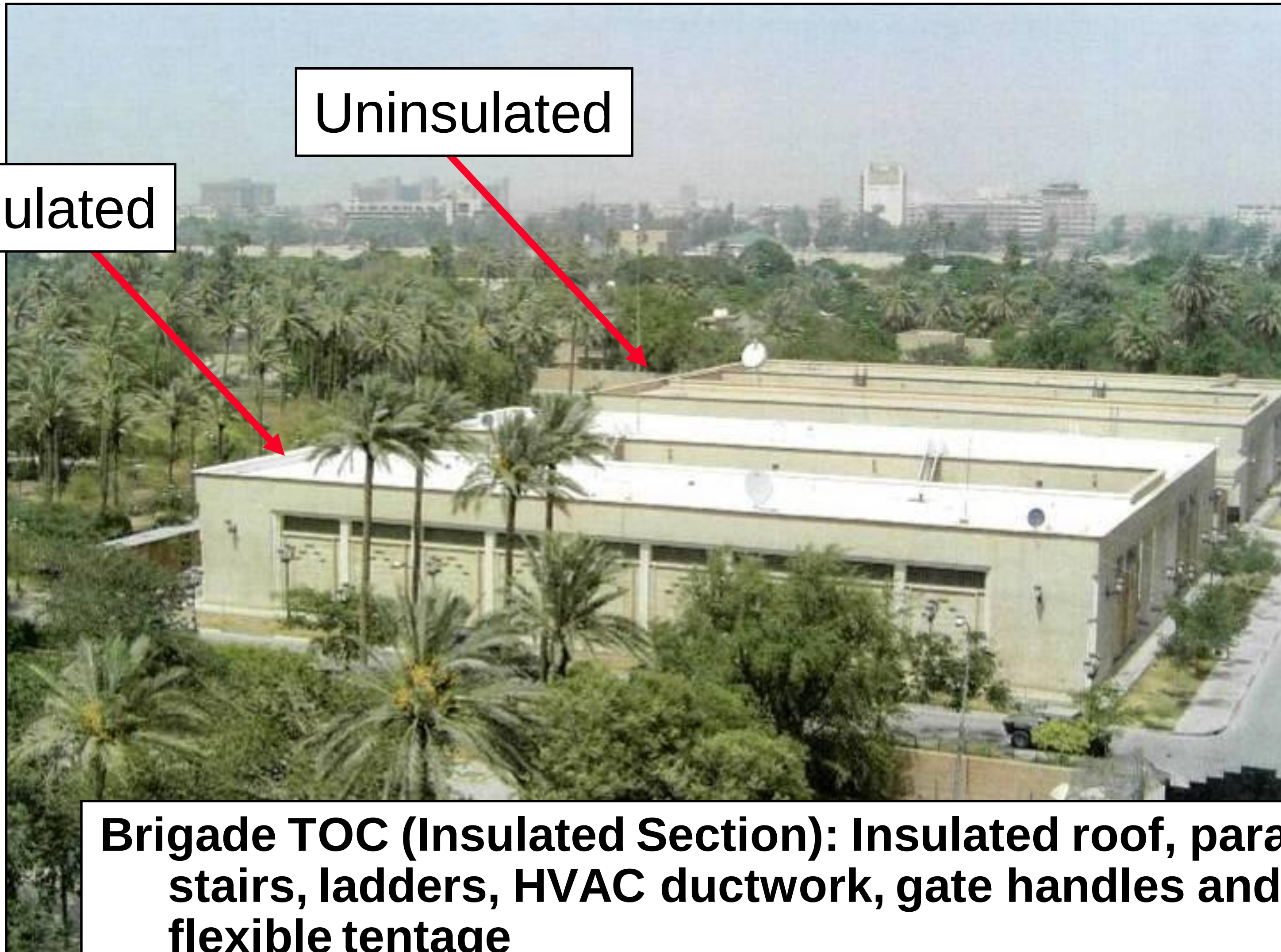
Comparison of Tentage Insulation & Associated Cooling Requirements		
Tentage Insulation	ECU (tons)	kW (cooling)
Double-Lined	6	21
Spray-Foam / Other Insulation	4	8.8

Double-Lined Tent, Ali Al Salem LSA - Kuwait (6-ton ECU)

Transient Housing – Approx 220 Tents

Comparison of Tentage Insulation Ali Al Salem LSA - Kuwait		
Tentage Insulation	kW (cooling)	Total Demand (MW) (220 Tents)
Double-Lined	21	4.62
Spray-Foam / Other Insulation	8.8	1.94

Baghdad, Iraq - 2004



Brigade TOC (Insulated Section): Insulated roof, parapets, stairs, ladders, HVAC ductwork, gate handles and flexible tentage

249th Prime Power Battalion

Prime Power services replace tactical generators with centralized power generation and distribution.

- Typical power plants consist of four 750 kW gensets providing up to 2.25 MW continuous output and 3 MW peak.
- Fuel consumption for the typical plant ranges from 40 to 220 gallons per hour.

"Match the power source to load requirements… A common violation of this guideline occurs when a large prime power plant is installed to provide power to a relatively light load… Prolonged misuse will cause carbon fouling and buildup, reduced engine performance, and eventual engine failure."

-Engineer Prime Power Operations Field Manual

Summary

- Tactical organic electrical generation will only provide enough power to those specific units and their equipment. Base operations will have additional unspecified power demand
- Power requirements at commands above the Corps level fluctuate constantly and are typically not optimized for efficiency.
  Mindset: "Just add another generator"
- We have a fundamental challenge in the way we currently provide for and distribute power and energy. We need to holistically treat tentage, other temporary facilities, ECUs, generators, and mission equipment as a single system
- Currently, renewables will only provide a small percentage of the overall electrical demand, due in part to: area required, transportation to the remote sites, and O&M *(Passive solar water heaters an exception)*
- We will need to focus not only collecting any definitive data on how we currently do things, but to show a way forward to greatly improve the effectiveness of this mission
- Operational and Tactical Commanders did not stress or were concerned with energy efficiency, it was all about power reliability (mission accomplishment) & soldier quality of life

Recommendations

- Develop facilities with improved building envelope: tightness and insulation
  - Because many of the HVAC systems are not controlled, the user would be compelled to make personal changes because of the improved building tightness
  - ECUs to support the facilities would be sized smaller than current configurations, reducing both power demand and energy
- Conduct a full-scale base camp demonstration (battalion size or higher), to quantitatively determine requirements:
  - Water
  - Power and Energy
  - Waste Management
- Conduct a power study at one of the major command sites in Afghanistan to optimize power generation and load management
- Develop fully integrated pre-engineered buildings with renewables; DC → DC power, no inverter required
- Clarify/Change FM 3-34 power demand values for base camps listed below

Table E-14. General planning factors for electrical power and distribution requirements: *Facility Electrical Power and Distribution Requirements*

Installation 0.7 kW per man

Hospital 1.6 kW per bed

Questions?

Contact Information

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Backup Slides

Power Requirements for Selected TOCs "*Power Assessment for IBCT*", 1 Nov 01 Mobile Electric Power

	Brigade Main	Inf Bn Main	Bde Spt Bn Main	RSTA Main	FA Bn Main
Total Demand (kW)	134.4	54.1	73.7	61.0	25.2
GEN Sets (kW)	198	76	111	99	48

- An inventory of each power consumer and its operating status was taken. Equipment list was compared to the list of equipment assigned to the shelter.
- An extensive effort was made to account for the significant amount of equipment that consumes power not on the unit's MTOE (printers, plotters, coffee pots, etc.).
- Power measurement and recording equipment were used.
- In cases where the mission equipment was either not present and/or not functioning during the assessment, the team used as input, the power consumption for each item of equipment specified by the manufacturer.

Ft. Lewis, WA, April/May 2001

Base camp electric power generation utilities are sized to supply peak anticipated loads for the population served. Army Technical Manual (TM) 5-811-1/Air Force Joint Manual (JMAN) 32-1080 provides per capita loads for a range of force characteristics. Based on that reference, the worst case power demand scenario for an Army or Air Force installation is 3 kilowatts (kW) per capita. Table 11 summarizes the power generation requirements for each force level based on that sizing criterion.

Table 11. Base camp electric power utility loading summary.

Force Level	Company		Battalion		Brigade	
Units	US	Metric	US	Metric	US	Metric
Population (capita)	170	170	750	750	3,000	3,000
Power						
Generator Size	510 KW	510 KW	2,250 KW	2,250 KW	9,000 KW	9,000 KW

kW/person	3.0	3.0	3.0

ERDC/CERL TR 04-DRAFT, September 2004

Energy Management in Iraq

- Insulation of buildings, AC units, ductwork, and water tanks, to reduce frequent generator fuel supply convoys, using TC Ceramic (www.capstonemfg.com)

- Installation of radiant vestibule liners from Natick Soldier Support Center on hospital tents in Mosul and Tikrit

- Medical Brigade TOC in permanent bldg, existing generator was 500kW, for 60 personnel and equipment (incls. 150-tons of A/C) (8.3 kW / person)

LTC Bill Stein, 2004

Team Experience in the CENTCOM AOR

Two team members have deployed

- Bill Stein (LTC, Brigade Engineer) was in Iraq during 2004 and conducted building and HVAC energy efficiency measures, to reduce fuel convoys
- John Vavrin was in Afghanistan during all of 2009 and did a qualitative energy survey and technical report (TBP) of U.S. facilities during his deployment.

  John was also on the CENTCOM Engineering Staff during all of 2004

Other Army and DoD Partners Addressing These Same Forward Deployed Facility Objectives

USACE:

- ERDC-CERL SBIR/STTR research for microgrid development
- 249th Engineer Battalion at Fort Belvoir, VA, and its …
- Prime Power School at Fort Leonard Wood, MO

RDECOM:

- TARDEC-NAC
- CERDEC
- Mobile Electric Power
- Natick Soldier Center

Defense Logistics Agency

Rapid Equipping Force and Power Surety Task Force

Navy Shipboard Power

Marine Expeditionary Forces

COP in a Can

Description: Combat Outpost (COP) for 50 Warfighters including billeting, kitchen, laundry, shower, latrines, and new wastewater treatment system

Capability/impact: Compact, lightweight system that is rapidly deployable offering full camp facilities for 50 personnel

Components: 3 prepackaged tricon containers equaling one 20 foot container, 60 kW Generator (1.2kW/person), 2 tricons are standard and kitchen tri-con is expandable

Container #1: integrated system - shower(1), latrines (2), sinks (2), laundry, wastewater treatment, 3K black water and fresh water bags

Container #2: field kitchen incorporating tray ration heaters, 32' airbeam tent

Container #3: two 32' airbeam tents, inflation system, 25 double bunks, chairs

What will be delivered: 2 prototype camps incorporating new wastewater treatment system, adequate testing to prove performance & safety, safety release

CONUS Training Facility Base Camps

The National Training Center (NTC) at Fort Irwin, CA provides a highly realistic example of in theatre conditions.

- Energy sources on the training range are contractor owned and operated fossil fuel generators
- Little, if any data is available on the fuel usage and total inventory


Iraqi Village


Tactical Genset with Lighting


Insulated Foamed Tents

CONUS Training Facility Base Camps

Camp Atterbury, IN provides contingency operations training to troops.

- The realism focuses on the soldier's perception rather than physical duplication: electrical service is provided by the camp distribution system
- Contingency Operations Location 3 (COL 3 - Nighthawk) is metered independently and may provide useful data on electrical usage


Tent Electrical Connections


High Voltage Distribution Boxes


FEMA Trailer Sleep Space

Photographs:
B-Huts & Base-in-a-Box, Camp Spann, Mazar-e-Sharif

Photographs: Pre-engineered/ Relocatable Buildings & B-Hut Expanse, Camp Phoenix, Kabul

Photographs: Corrugated Metal, Maintenance Facilities, Camp Phoenix, Kabul

249th Prime Power Battalion

- **Planning for future power needs is a continual challenge for engineers in the 249th.**
  - Essential for electrical efficiency
  - Easier in early camp development

- **Infrastructure, multiple tenants, and changing requirements make power system modification difficult in developed camps.**

- **Real estate is scarce and requires additional protection: Renewables should be structure integrated**

Why is energy important as a planning factor?

- When generators are used to produce electricity, there is a non-linear relationship to the amount of fuel used versus the total energy (kWh) produced
- When generators are loaded at 30% of the maximum power rating they will break down three times faster than one loaded at 90%, but will use approx 20% more fuel to produce the same number of kWh

The Difference Between Power and Energy

- Power is the maximum you will use or the maximum generation that will be provided. Units are in kilowatts (kW). Example is a 100-kW generator for a maximum load in a Battalion Tactical Operation Center

- Energy is the instantaneous power multiplied by time for each hour, usually measured for a month. Units are in kilowatt-hours (kWh). Example is that the typical U.S. house uses 1,000-kWh per month

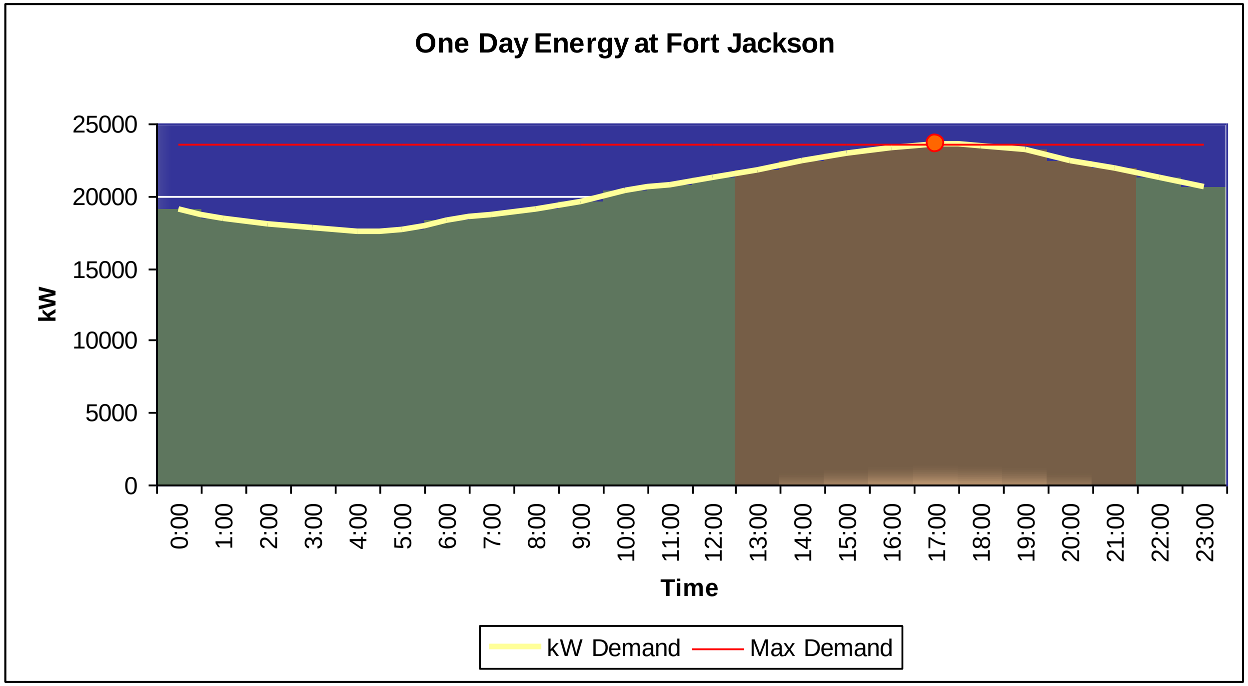
Power vs. Energy

Base camp electrical needs must be addressed as both power and energy requirements.

- Power is the **demand** (kW) needed instantaneously to supply the load
- Energy is the **usage** or power consumed (kWh) over time by the load

The pale yellow line is the power (kW)

The area under the power curve is energy (kWh) consumed



Data Collection

- The 249th Engr. Bn (Prime Power) was contacted and has promised data from its contracts for fuel used versus energy produced in Iraq and Afghanistan

- Site visits to training areas in the U.S. at Fort Irwin, CA, and Camp Atterbury, IN, produced little useful data

- Interviews with soldiers that have been deployed has produced little useful data

Energy Recommendations

- **Develop energy requirements keeping in mind that these requirements creep up as base camps mature.**
- **Develop an Energy transformation plan**
  - Tactical
  - Medium Voltage
  - High Voltage
  - Commercial Interconnection
- **Ensure that efficiency of existing power and use.**
- **Restore and protect the host nation power assets.**
- **Improve the United States' deployable power generation capability**

Pre-configured modular units utilize 750 kW generators to support 500 men

General Notes

2004 Base Camp Planning Workshop

- Develop energy requirements keeping in mind that these requirements creep up as base camps mature.
- Develop an energy transformation plan
  - o tactical
  - o medium voltage
  - o high voltage
  - o commercial interconnection
- Ensure the efficiency of existing power and use.
- Restore and protect the host nation power assets.
- Improve the United States' deployable power generation capability

Pre-configured modular units utilize 750-kilowatt (kW) generators to support 550 men (1.4 kW / person), reference 2006 Air Command & Staff Study, Basic Expeditionary Airfield Resources

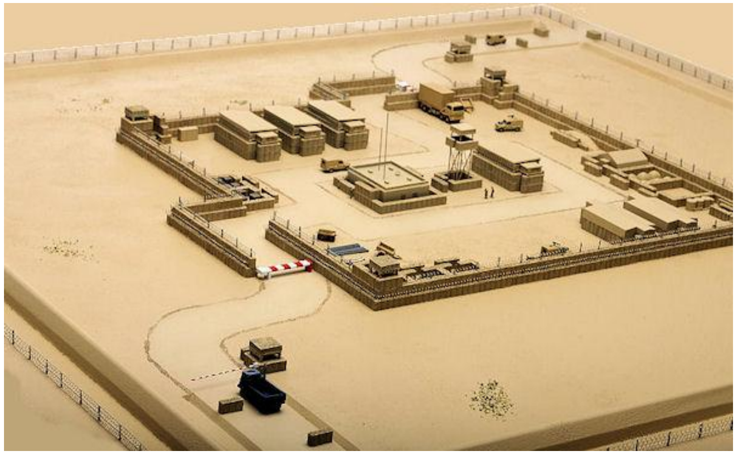
Applications of mobile/tactical electrical power

Applications	Power Class (kW)						
	2	3	5	10	15	30	60
Mobile kitchen units	X						
Combat support systems	X						
Communications systems	X						
Missile systems	X	X	X	X	X	X	X
Causeway systems		X	X				
C4ISR systems		X	X	X	X	X	
Weapon systems		X	X	X	X	X	X
Laundry units				X			
Refrigeration systems				X			
Well kit					X		
Printing plant					X		
Topographic support systems					X		
Hospital maintenance					X		
Bakery plant						X	
ADP support systems						X	
Water purification						X	
Aviation shop sets						X	
Field hospitals/schools							X
Aviation ground support							X
Earth satellite terminals							X

ERDC/CERL TR 05-36, December 2005

Systems Integration Laboratory – Base Camp

- Plans are underway to resource & build an SOS Base Camp SIL in CONUS
  - Simulated operational environment; complete base camp architecture (not just life support systems)
  - Multiple Company & Platoon sized base camp SILs, instrumented for data collection
  - SOS Architecture Exploration, Technology Experimentation, Product Testing, Integration & Validation
  - Dual use as a power projection or training asset for CONUS Army installation
- Leverage experience & knowledge gained by USMC Experimental FOB at Quantico
  - Marine Corps Warfighting Lab will establish and evaluate a temporary battle position (Platoon & Company size) for experimentation
  - Simulate OEF energy and water demand and to evaluate material and non-material solutions that will increase forward operating bases self-sufficiency



ExFOB Timeline

- **15-19 Feb 10 - Phase-1**
  - USMC Only
  - Optimize USMC Equipment
- **22 Feb – 5 Mar – Phase-2**
  - Industry Demonstrations (COTS)
- **May – Phase-3**
  - Initial "Implementation Team" to OEF
- **2 – 13 Aug – Phase-4**
  - Industry Demonstration of technology other than COTS
  - RFI expected to be released in May

Alternative (Renewables) Energy Demonstration Project at the ANA “22 Bunkers Complex”

Purpose: To demonstrate the benefits of small-scale photovoltaic (solar) and wind generating systems at the “22 Bunkers Complex”
- Project Site location is east side of Kabul

Project Scope: A design-build of the following systems (incl. battery backup) to distribute power for two security towers and three guard buildings.
1. Four solar (photovoltaic /PV) systems (~ “6” kW ea)
2. One combo solar and wind hybrid system (~ “8” kW)

Costs ($)

Organization	FY09 – Initial	FY10 – FY11 Follow-up
AED/CERL	$900K	$50K

Timeline

Event	NTP	Begin Evaluation	End of Evaluation	Report Due
Date	Mar 09	~ Feb 10	~ Feb 11	~ Mar 11

Goals
1. To determine life cycle costs of: (a) the base-line condition and (b) the installed systems
2. To determine the simple payback/SIR of the installed systems
3. To determine the electricity production efficiency
4. To assess and optimize a controls protocol for energy production, storage, and distribution
5. Conduct a limited energy reduction assessment
6. To teach energy conservation and renewables to the faculty and cadets of NMAA

Measurement and Verification (M & V)
- Contracted to conduct M & V for 12 months
- CERL/University of Illinois to validate all results & write tech report